MANN — SEED CHARACTERISTICS IN THE NATURAL REPRODUCTION OF CONIFEROUS FORESTS

The University of Minnesota

STUDIES IN THE BIOLOGICAL SCIENCES NUMBER 2

THE IMPORTANCE OF SEED CHARACTERISTICS IN THE NATURAL REPRODUCTION OF CONIFEROUS FORESTS

BY

JULIUS VALENTINE HOFMANN, M.F., Ph.D.

Special Lecturer on Sylviculture in the University of Minnesota

MINNEAPOLIS
Bulletin of the University of Minnesota
June 1918

PRICE: 25 CENTS

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PREFACE

Acknowledgment is made to Dr. F. E. Clements for assistance in planning the laboratory work and to Professor J. P. Wentling, under whom the sylvicultural work was done, for many suggestions in the development of the study and in the interpretation of the data. The author is indebted to the United States Forest Service for the investigations he conducted while at the Priest River and Wind River Experiment Stations, especially to Mr. D. R. Brewster for his help at the Priest River Experiment Station. All plates are original except Plates I and II, for which credit is given the United States Forest Service.

JULIUS V. HOFMANN

March 1, 1914

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THE IMPORTANCE OF SEED CHARACTERISTICS IN THE NATURAL REPRODUCTION OF CONIFEROUS FORESTS

Introduction

Almost all coniferous trees are dependent on seed for their perpetuation and distribution. Although in their natural state coniferous forests have maintained themselves and extended their boundaries with only minor or local changes of composition, this apparent equilibrium in nature is easily upset by man's exploitations, such as destructive lumbering, repeated fires, and unregulated grazing. The effort to find the cause for the ease with which this climax type of the plant kingdom is disturbed or entirely replaced led to a study of the seed.

This study has brought out many valuable facts about seed characteristics and their importance in the perpetuation and distribution of the forest. Seeds and their behavior have been studied in the laboratory and in the field with special emphasis on the importance of size, vitality, length of time required to germinate, and other characteristics.

Amount of Seed

The production of seed is an important factor in the perpetuation of the tree species, although the periodicity of seed years and quantity of seed produced by one species may vary widely from these same factors in another species. The variations of seed production of one species are often weighed against the same factors of another species, to advantage or disadvantage as the case may be. This appears to be true when associated species such as yellow pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) or Douglas fir (*Pseudotsuga taxifolia*), hemlock (*Tsuga heterophylla*), western red cedar (*Thuya plicata*), and western white pine (*Pinus monticola*) are considered. The yellow pine is able to compete successfully with lodgepole pine under conditions favorable to the yellow pine. The lodgepole pine is, however, a much more prolific seeder, producing greater quantities of seed than does the yellow pine. What the lodgepole pine loses in ability to contend with unfavorable conditions, it gains in having many more seeds and consequently more seedlings with which to begin the struggle.

This is also true of the hemlock and its associates. If the enormous quantity of seed produced annually by the hemlock had the same chances of success as the species with which it associates, such as the Douglas fir, western white pine, and larch (*Larix occidentalis*), the entire forest would

soon be of hemlock. The small seed of the cedar is a good example. Although there is much seed of this species produced annually, the fact that it is small, produces a small seedling, and requires exceptionally favorable conditions for germination and establishment, limits the species and prevents it from getting entire possession of the ground.

In the Lake states, the jack pine (*Pinus divaricata*) produces many more seeds than the white pine (*Pinus strobus*) or the Norway pine (*Pinus resinosa*), and these species are always in keen competition with one another, resulting in the triumph of the jack pine in localities favorable to it.

Periodicity of the seed years is variable; so much so that it can not be considered in any practical application in planning for future forest work. It must, however, be considered in determining when the latest heavy crop of seed was produced. The forests produce seed sometimes annually and sometimes at periods of two or three years or even more. It is sufficient to know for the purposes of management, whether the latest crop was a sparse, medium, or heavy one.

In any average seed year, a forest furnishes enough seed to produce, under favorable conditions, an adequate stand of seedlings.[1] The heavy toll of rodents, fungi, drought, frost, and other unfavorable germination conditions, however, reduces the number of seedlings resulting from a single crop to a minimum.

In regard to seed production Darwin says: "Large numbers of seed are destroyed. The greater the chance against any given seed reaching a suitable locality and attaining maturity, the larger the number of seeds must the plant produce in order to maintain its numbers and as a general rule the smaller will the individual seeds be. On the contrary the greater the chance that each seed enjoys of arriving at maturity, the smaller the number of seeds that is necessary, and in such cases it is an advantage that the seeds should be large."

Distribution of Seed

Many species of coniferous trees bear seed with wings attached, being thus adapted for wind distribution. Most of the seeds have a wing attached to one side of the seed only. In an ordinary wind of ten or twelve miles an hour, such seed when released from the cone begins a downward spiral course and lands within 150 feet of the base of the tree. Since in a large part of our coniferous forests there is usually little wind in the autumn, or seeding time, wind can be considered a factor in seed distribution for only short distances from the seed trees. To be sure, the occasional blast of wind at the higher altitudes, blowing at the rate of seventy-five miles an hour, as has been measured by the writer in the Cascade

[1] Raphael Zon, Seed production of western white pine. *United States Department of Agriculture, Forest Service Bulletin* no. 210.

Mountains of Washington, may carry an occasional seed for a long distance, but satisfactory reproduction over large areas never results from a few seeds sown in this way.

Animals play a rather incidental part in seed distribution, and the carrying of seed by birds may account for the occasional trees found in unusual places. The most striking instance of animal distribution is seen in the yellow pine regions where squirrels, chipmunks, and mice collect and cache seeds and cones. Usually the caches are under logs, in stumps, or other hiding places. Often on the grassy slopes of the yellow pine region squirrels store separate cones under tufts of grass. The writer has examined and collected cones from such caches that covered areas 200 square feet or more. Mice also cache small piles of clean seed under grass tufts. Naturally rodents do not find all of the stored cones and seed, and in this way they become planters of seed even though they take heavy toll for their work. This accounts for the patches of yellow pine reproduction on some of the grassy slopes of western Montana and Idaho. Tufts of yellow pine have been found containing from ten to twenty seedlings.

METHODS OF STUDY

To determine seed distribution, belt transects 8¼ feet wide were run 2½ chains apart, covering 5 per cent of the total area, thus crossing it often enough to get representative areas under all conditions of moisture, shade, exposure (as to slope), and soil.

The belt transect shows the continuous conditions through the vegetation of a formation and gives graphically the relations of the various aspects and situations. It furnishes a record of the heterogeneity of the area in respect to species and soil conditions. The transect is preferable to the plot or quadrat in most instances, because the quadrat gives only a local record, and does not give topography and circumstances leading from one homogeneous formation to another.

Notes were taken on the kinds of soil, whether silt, sandy, rocky, clay, etc., vegetation cover, condition of soil, whether mineral or covered with humus, duff, or litter, and amount of charred logs and slash on the ground. Number and age of each species of seedlings present were recorded with conditions under which each individual or group of seedlings was found, as to soil, shade, or protection by logs or slash.

The following detailed report of an area studied in northern Idaho shows the methods used:

Designation.......... Kaniksu-Fidelity Lumber Co., March 18, 1907.
Location.............. Sec. 26, T. 57N., R. 5W., Boise M.
Topography.......... Rolling, traversed by Pine Creek—a non-drivable stream—and the West Branch River—a drivable stream. Slopes and ravines shown by map.

PLATE I

The Migration Chart shows the area divided into units having similar factors influencing reproduction. These areas are designated by the letters of the alphabet. A letter appearing on two or three areas indicates that these areas are similar.

Areas A, B, C, and D are all within seed plots under about 50 per cent shade with sparse annuals and ground cover of duff, humus, and litter. The seed trees in the plots are healthy except in C and in the edge of D where they have been badly damaged by fire.

E is an area of unburned, partially piled slash on a steep north slope of 20 to 40 per cent, with scattered small trees of hemlock and cedar. The ground cover is of sparse annuals and patches of duff, humus, and litter.

F is an area of unburned, partially piled slash on a southeast slope of 15 to 20 per cent. The ground cover consists of scattered annuals, and a large per cent of the soil is covered with litter and duff. Scattered trees of hemlock and small cedar were left standing on this area.

G is practically level. The greater portion of it is unburned slash, partially piled, and the northern part of it has a pole stand of grand fir and cedar. The ground cover consists of a few annuals and litter and duff with some exposed places of mineral soil.

H is a south and west slope of 10 to 40 per cent, and is a very dry and hot situation. The north half of this area is covered with slash, piled but unburned. The ground is covered with scattering annuals and tufts of grass, except along the West Branch River where there is a heavy cover as previously described.

J is the general broadcast burned area of flat benches and slopes. The ground cover is described in the general description.

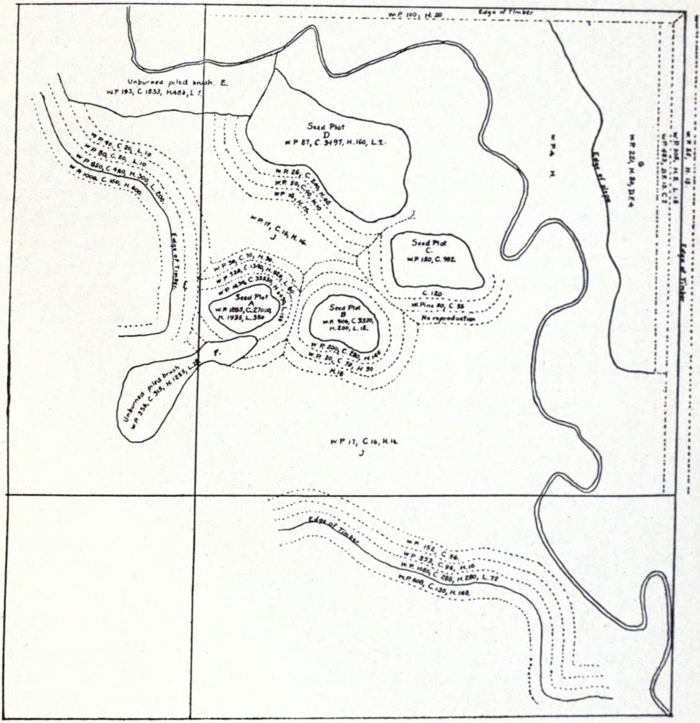

PLATE I

Showing the migration of the seed from the seed trees

Soil.................. Silt and sandy loam, dry, gravelly on hillsides.
Condition before cutting. Forest mature and over-mature consisting of two-age classes of 100 years and 200 years. Considerable fungus and insect injury.

	White Pine	White Larch	Red Fir	Cedar	Cedar Poles
Average total height of trees (feet)	140	140	120	120	75
Average diameter of trees (inches)	20.1	20.4	20.4	27.0	12.8
Average number of trees per acre	27.4	3.7	0.8	2.8	17
Average stand feet B. M. per acre	17,564	2,068	358	2,496	545
Per cent of total stand	79	11	2.5	7.5	
Seedlings less than 5 feet high per acre—per cent of stand	30	10	10	50	
Trees between 5 feet high and 6 inches D.B.H. per acre	10	2.5	2	16	
Number trees over 6 inches D.B.H. to be left	4.5	1.5	0.5	5.2	

Reproduction.......... Hemlock and cedar heavy throughout. White pine and larch in groups in openings.
Utilization............ All merchantable timber, living and dead, standing and down, cut.
Brush disposal......... All unmerchantable timber, slashed and broadcast, burned.
Burned-over........... June, 1910.
Seed years............ Good seed crop in 1909 and a fair crop in 1911.
Sylvicultural system.... Clear cut with seed plots.
Condition at time of examination, September 1912.

Ground cover. Scattering individuals of wild rose (*Rosa*), bearberry (*Arctostaphylos*), thimble berry (*Rubus*), Solomon's seal (*Polygonatum*), fern (*Pteris*), fireweed (*Epilobium*), mountain maple (*Acer*), willow (*Salix*), service-berry (*Amelanchier*), vetchling (*Lathyrus*), thistle (*Carduus*), horse-tail (*Equisetum*), lupine (*Lupinus*), alder (*Alnus*), goldenrod (*Solidago*), spiraea, lamb's quarters (*Chenopodium*), various kinds of grasses in tufts and heavy stands on river bottom flats, and clover (*Trifolium*) along the road sides, make a ground cover of about 50 per cent. This, however, is not an even cover as the vegetation is in groups with many open or sparsely covered areas.

The areas burned over are quite free from any material except some scattered charred logs. The mineral soil is exposed in some places and other areas are covered with humus and duff. Unburned strips covered with pine needles and wood litter occur along the timber. The soil has been in excellent condition for reproduction since the burn of 1910, and was in good condition at the time of the examination.

The cut-over area as a whole is naturally divided into units which have similar factors influencing reproduction, as seed-plots, slopes, slash, etc.

The Migration Chart shows that the reproduction is much heavier on all of the areas where the slash was left unburned. This is undoubtedly due to the seed and seedlings left on the ground at the time of cutting, as there are no seed trees in the vicinity of areas E, F, and G to reseed them. All of the burned areas adjoining have no reproduction. Areas E, F, and G have seed trees of cedar and hemlock, but no white pine.

As shown by the Migration Chart, the distance of seeding from the seed trees seldom exceeds 2 chains.

Conditions where the seedlings were found were very similar to the conditions of the area in general, indicating that no seed had been sown on the areas farther than shown by the Migration Chart.

These points were borne out by several areas studied in this region. They were also verified by intensive studies on the Yacolt burn of 1902, now in the Columbia National Forest in Southern Washington. This burn covers over 600,000 acres, and areas of hundreds of acres have no green trees left.

The distance of seeding to produce an adequate stand of seedlings, 500 to 1,000 per acre, in the localities studied on the Yacolt burn was found to be 2 to 4 chains for Douglas fir, noble fir, and amabilis fir; 3 to 5 chains for hemlock, and cedar; and usually 2 chains for white pine.

Germination of Seed

The length of time the seeds of a species require for germination often determines the success or failure of that species on certain sites. On some sites germination conditions are favorable for only a short period, consequently in order to take advantage of such periods a seed must germinate quickly. Where seeds of western yellow pine germinate in eight to ten days, the seedlings have a decided advantage over the western white pine, which may take fifteen to twenty days or more to germinate under the same conditions. In situations where the conditions are favorable for only three or four weeks, the early germinating seed assures success to that species, while the seed which germinated slowly may be only beginning to grow when unfavorable conditions occur, with a consequent loss of all germinating seed which has not established its seedlings.

On the other hand, the habit of dormancy may prove advantageous to a species by preserving the seed until a favorable season stimulates it to growth. By the refusal to respond to the first short favorable period for germination, the following drought may be avoided. Seeds of this character are often early spring germinators after one, two, or even several seasons of storage. This characteristic has been found in western white pine, Douglas fir, sugar pine, incense cedar, and others. When these species were sown in the nursery or seed spotted in the field, the germination

continued over several seasons. Instances of field sowing of Douglas fir and sugar pine have been found where the results were considered a failure the first season after sowing, and some germination appeared the second season, while the third season produced a very satisfactory germination. While this may occur under favorable conditions of sowing, the length of the dormancy period in nature under an environment less favorable for germination is still further prolonged.

Size of Seed

That the early development of the seedling is dependent on the food stored in the endosperm of the seed was shown by tests of seed of western yellow pine, Douglas fir, western hemlock, and western red cedar, in sand, in soil to which nutrient solutions had been added, and in potting soil made up of leaf mold and sand. The following nutrient solution was used:

To each liter of water was added:

1\. gram calcium nitrate
0.25 " potassium chloride
0.25 " magnesium sulphate
0.25 " acid potassium phosphate

The soil was moistened with this solution and always watered with the same solution.

The seeds germinated equally well under all conditions, but the differences were very soon noticeable after germination.

Seedlings germinated in the sand came above the ground and appeared as good as those grown in the potting soil or in the nutrient solution. When the seed-coats were shed, they began to fail and apparently were unable to get any nourishment, or at least not sufficient to make any growth. After the cotyledon stage, these seedlings did not appear healthy and many of them soon developed their winter or resting buds. The seedlings in the potting soil and in the nutrient solutions made good growth and did not develop any buds until they had passed through the regular growing period. Those grown in distilled water grew until the food contained in the seed was exhausted, and then died.

In this connection it was noted that the seedling growth the first season was directly proportional to the size of the seed. This fact gives species with large seeds an advantage over species with small seeds, for example, yellow pine seedlings would become established on dry sites where hemlock or cedar would fail. The yellow pine would be able to send down roots to the moist soil, due to the food stored in the seed, while the small-seeded species would have to depend on obtaining nourishment and moisture from the surface soil, and consequently fail. Table I shows the results of experiments with different depths of cover in loam soil to determine the influence of food stored in the endosperm.

Plate II

View of Yacolt burn of 1902, on the Columbia National Forest in southern Washington, showing edge of the green timber at the extreme right of the view; no other green timber in sight. This is part of the area where the reproduction study was made. Looking northwest from Lookout Mountain.

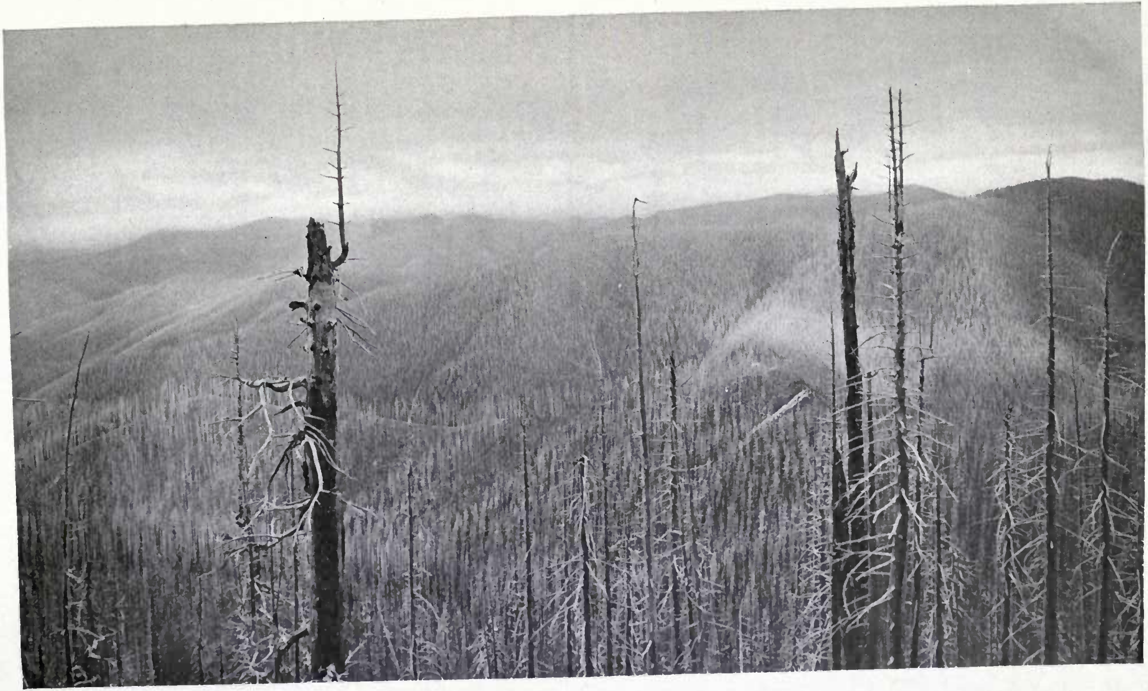

PLATE II

TABLE I

Species	Depth of Cover—Inches	Per Cent Germinated	Per Cent Appeared above Ground
Pinus ponderosa	1	82	82
	2	83	74
	3	71	42
	4	36	0
Pseudotsuga taxifolia	½	93	93
	1	87	85
	1½	72	64
	2	67	50
	3	42	3
	4	17	0
Tsuga heterophylla	¼	96	96
	½	92	76
	¾	86	50
	1	64	5
	1¼	42	0
Thuya plicata	⅛	78	78
	¼	64	52
	½	42	24
	¾	25	4
	1	26	0
	1½	19	0

The above table shows that seedlings will grow up through soil a distance which is in direct relation to the size of the seed. The development of the seedlings showed that they will grow to a size which is in direct relation to the amount of nourishment stored in the seed. If the seedling can not reach the surface before the supply of nourishment in the seed is exhausted, it must die. On the other hand if it is able to get above the ground, even as a final effort, the cotyledons open up at once and turn green, enabling the seedling to obtain food through a new source, viz., the chlorophyll.

It follows from this that seed may often germinate when covered with litter and duff and the seedling may not reach the surface, on account of the size of seed involved. Here then the larger-seeded species has an advantage over the smaller-seeded species.

The occurrence of seedlings or trees of any species on any site indicates that the site is, to some extent at least, favorable to the species found there, but it does not show that any other species would not establish itself or develop well there if given an opportunity. It is frequently merely a question as to which species first gets possession of an area immediately after the virgin forest is removed, or which species first had the opportunity of migrating there. In other instances it is clearly a matter of competition between species as to their ability to withstand the conditions of the site involved.

As one looks at the peaceful forest one should remember that underneath the calm serenity of the scene there is a bitter struggle, a relentless internecine warfare between the trees already established there and those that are striving to enter from without.

Soil temperature, soil moisture, aeration, and light are among the ecological factors which determine the establishment of a forest and determine the types within a forest. A wide variation of any one of these factors on different sites does not mean that the varying factor is the one which determines the type. Other factors, varying less, but approaching nearer to the limit of favorable conditions would have a greater influence on the germination of the seed or the establishment of the seedling. All the factors must be taken into consideration, and also the limits of each under which the seedlings will grow. While the moisture in the soil in two different localities may be equal, the soil texture may have a decided influence on the availability of the moisture for plants; that is, there would be a decided difference in the wilting coefficient. The fact that the surface soil often dries out, while at a depth of about six inches moisture may be present on protected slopes and absent on exposed slopes, gives decided advantage to seedlings with deep roots formed early in their development. For this reason, yellow pine has an advantage over hemlock and its associates in the forests of western Montana and Idaho. For the same reason, Douglas fir is able to establish itself on the drier slopes of the Cascades, while hemlock and cedar fail. A south slope covered with yellow pine or Douglas fir, and a north slope covered with hemlock, white pine, cedar, and other species, does not mean that each of these species is in its optimum habitat. It is rather a question of competition between species and of establishment. Yellow pine would produce excellent forests on some of the slopes occupied by other species if it could establish itself there. It is, however, crowded out by the large number of seedlings of the other species. On the other hand, the hemlock and cedar do very well under the conditions of the south slopes wherever they can get sufficient moisture to establish themselves. The reason these species are not in mixture all through the forest is not due to a lack of seed or even to the germination of seeds on the different slopes. An example of this nature was noted by the writer where two types met on a ridge. The south slope was seeded with seed from species found on the north slope. Seedlings of hemlock and cedar and larch were found germinating along with those of Douglas fir and yellow pine in the spring of the year, but in the fall only some of the seedlings of yellow pine and Douglas fir were left. The seedlings of the other species were unable to live through the dry period of the summer, due to their small roots and their inability to reach the moist layer of soil below the dry surface before they perished. These conditions are repeated year after year, and yet the type remains unchanged. It is very noticeable

that, wherever a ravine or spring keeps a south slope moist, seedlings from the species of the north slope are found.

Different slopes often get about the same amount of precipitation, but there is such a marked difference in the evaporation that the exposed slopes dry out while the north and protected slopes remain moist.

The effect of site exposure is clearly shown by the following summary table of meteorological data gathered near the Wind River Experiment Station at a station on a south slope, at an elevation of 2,150 feet, one on a north slope at an elevation of 1,750 feet, and one on an intermediate flat at an elevation of 1,150 feet. All stations were in the same watershed and less than one-half mile apart.

The important features of these results are the marked differences in evaporation during the critical drought period. During August the evaporation from water surface on the south slope was 15.1 inches, while on the north slope it was only 1.8 inches, with a corresponding moisture content of the surface soil on the south slope of only 1.0 per cent, while the north slope contained 6.5 per cent. With this extreme dry surface soil on the south slope, there still remained 11.2 per cent of moisture at 6 inches deep and 10.4 per cent at 12 inches. This would support plant growth providing a large enough proportion of the absorbing root systems were contained in this layer of soil.

In the spring of 1913, 100 seed-spots of Douglas fir were sown on each of the sites, south slope, north slope, and flat, and 25 per cent of the spots on each site were protected by cone-shaped wire screens to prevent damage by rodents.

Three examinations were made. At the end of the season the seed-spots on the south slope had no seedlings, either in protected or unprotected spots, since all that germinated during the season died in the dry part of the summer. On the north slope the protected spots had an average of .69 seedlings per spot, and 44 per cent of the spots contained seedlings, while the unprotected spots averaged .25 seedlings per spot and 22 per cent of the spots had seedlings. On the north slope there was no loss of the total number germinated. On the flat the protected seed-spots averaged 2.85 seedlings per spot and 88 per cent of the spots had seedlings, while the unprotected spots averaged .31 seedlings per spot and 34 per cent of the spots contained seedlings. The loss of the total germination on the flat was 6 per cent.

In the spring of 1913, the following species were sown under wire screens on each site: Douglas fir, noble fir, western white pine, and western yellow pine. An area of about 16 square feet was sown to each species, one half of the area being put in as a regular seed-spot and the other half broadcasted without preparing the soil.

TABLE II

SUMMARY OF METEOROLOGICAL DATA OF STATIONS ON SOUTH SLOPE, NORTH SLOPE, AND FLAT

Readings averaged by months

	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Maximum temperature surface soil							
South slope		82.0	113.0	109.2	129.4	101.5	79.5
North slope		71.0	81.5	77.2	82.4	63.5	61.7
Flat		80.0	109.5	117.5	139.2	93.0	69.5
Minimum temperature surface soil							
South slope		37.0	46.0	48.2	46.8	43.2	38.2
North slope		38.0	48.7	52.5	51.0	44.0	37.5
Flat		37.0	47.7	47.8	45.0	38.2	33.7
Set maximum temperature surface							
South slope	46.0	59.2	63.2	90.0	121.0	71.7	56.2
North slope	46.0	56.2	63.2	69.2	68.8	54.5	50.4
Flat	44.0	60.0	69.7	92.2	104.6	75.7	56.5
Soil temperature six inches deep							
South slope	45.0	51.6	60.5	67.5	73.4	60.5	52.2
North slope	43.0	49.7	58.6	61.2	63.4	53.2	50.0
Flat	45.0	54.4	62.7	68.2	72.4	55.9	49.0
Soil temperature twelve inches deep							
South slope	44.5	50.9	59.2	63.2	69.2	60.7	52.6
North slope	42.0	49.0	57.5	59.0	61.4	53.7	48.7
Flat	44.5	51.9	60.5	64.7	67.6	56.2	50.0
Air temperature							
South slope	43.0	60.0	55.0	79.0	82.0	68.0	52.7
North slope	46.0	62.0	61.0	75.0	75.0	64.0	51.5
Flat	44.0	62.0	62.0	80.0	84.0	72.0	55.2
Relative humidity							
South slope		63.2	81.7	41.5	35.7	43.7	74.2
North slope		68.4	75.5	45.2	42.6	52.5	75.0
Flat		64.6	75.7	32.5	30.8	41.0	68.0
Evaporation from water surface in inches							
South slope		4.2	4.9	4.4	15.1	4.0	2.7
North slope		2.0	1.6	0.9	1.8	0.7	0.9
Flat		3.4	3.8	3.0	6.0	2.4	1.3
Per cent of water content in surface soil							
South slope	31.8	22.7	22.2	9.9	1.0	24.8	25.6
North slope	29.1	29.8	23.2	15.3	6.5	27.4	35.3
Flat	23.3	29.3	35.5	15.9	2.3	31.1	30.6
Per cent of water content in soil six inches deep							
South slope	30.5	27.4	21.2	18.9	11.2	28.7	30.5
North slope	35.9	23.1	25.9	23.2	17.5	26.8	32.1
Flat	26.3	28.9	25.7	24.0	17.4	29.4	30.2
Per cent of water content in soil twelve inches deep							
South slope	31.5	25.9	19.3	21.1	10.4	27.6	31.8
North slope	27.5	26.0	26.7	23.0	19.4	18.9	32.1
Flat	28.4	25.1	26.2	23.4	21.1	30.2	30.7

The sowing failed on the south slope. A few seeds germinated, but the seedlings perished during the dry season. The noble fir did remarkably well on the north slope, and the Douglas fir and white pine did fairly well, but the yellow pine failed. There was no loss of the total number germinated.

On the flat the Douglas fir did very well and had a 15 per cent loss of the total germination. The noble fir did fairly well, with a loss of 30 per cent of the total germination. The white pine germinated very little and had a loss of 46 per cent of total germination, while the yellow pine germinated very little, and 15 per cent of the total germination died.

The conditions under which the seedlings become established are shown in the following average summary of four areas studied in northern Idaho.

TABLE III

Conditions under Which Seedlings Were Found Established in Northern Idaho

	White Pine Per cent	Cedar Per cent	Hemlock Per cent	Larch Per cent	Grand Fir Per cent
Soil					
On humus......	3	2	7	1	9
On duff........	34	16	19	32	28
On wood litter..	25	22	58	17	8
On mineral soil..	38	60	16	50	55
Protection					
In shade.......	21	54	64	22	15
Under logs.....	8	4	8	8	25
In open........	71	42	28	70	60
Age					
1 year old......	37	74	87	25	2
2 years old.....	19	9	8	11	4
3 years old.....	34	16	4	55	35
4 years old.....	9	1	1	9	50
5 years old.....	1				9

In regard to the areas examined, the above tabulation shows that the white pine seedlings start about equally well on the duff, wood litter, and mineral soil, while the other species do not show any particular preference. In this study, moisture was found to be the controlling factor, and the other conditions recorded are usually favorable only where they produced better moisture conditions.

Effect of ground cover after burns or cuttings. An area was selected on a south slope at an elevation of 1,700 feet, where the ground cover of wild pea vine and brush was very dense. One square rod was denuded of all vegetation and the area beside it left untouched. Readings of air temperature at the height of the crowns of seedlings, and soil temperature at surface, 6 inches deep, and 12 inches deep were taken each week on the denuded area and in the adjoining area where the natural vegetable cover

was undisturbed. The object was to find the influence of ground cover following a burn or clearing. The results are summed up in Table IV.

TABLE IV

NATURAL COVER AND DENUDED AREAS

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
AIR TEMPERATURE						
Natural cover	60.8	59.2	70.7	*86.6	72.0	55.7
Denuded	72.2	64.4	84.7	102.8	76.2	60.0
SOIL TEMPERATURE						
Natural cover, surface	55.6	56.0	62.7	73.4	63.5	56.2
Natural cover, 6 inches deep	52.2	55.2	60.5	68.4	61.0	54.5
Natural cover, 12 " "	50.9	55.0	60.0	66.4	60.6	54.5
Denuded surface	74.5	67.5	92.5	124.2	89.2	64.5
Denuded 6 inches deep	57.8	62.0	68.0	78.7	67.0	54.2
Denuded 12 " "	56.3	61.5	67.0	74.4	66.2	56.2
PER CENT SOIL MOISTURE CONTENT						
Natural cover surface	33.3	32.4	23.1	10.5	33.4	36.5
Natural cover, 6 inches deep	21.3	26.7	20.0	12.9	29.5	26.5
Natural cover, 12 " "	23.9	20.5	18.6	15.4	28.4	27.7
Denuded surface	11.0	10.2	4.1	1.0	12.7	18.4
Denuded 6 inches deep	26.7	24.1	22.5	17.5	24.2	29.0
Denuded 12 " "	23.2	25.7	21.1	19.8	27.2	29.2

* Air temperature taken at crown on one-year-old seedlings.

Table IV shows clearly the effect of evaporation from surface soil when denuded, also the greater per cent of soil moisture at the 6-inch and 12-inch depths as compared with these same depths in the area having the natural ground cover of wild pea vine and brush. Although the surface dried out on the denuded area, the 6-inch and 12-inch depths still contained more moisture than in the area of the natural cover, due to the moisture being taken out of the soil by the roots and evaporated from the leaves in the area under natural cover.

The hot, dry surface soil shown in Tables II and IV accounts for the loss of one-year-old seedlings on these exposed slopes, while the moist, cooler surface under plant cover gives the young seedlings protection. The greater amount of moisture in the 6-inch and 12-inch depths on the denuded area and exposed slopes also shows why seedlings with deep roots early in their development will succeed on such slopes.

The following plates show the size of seedlings of various species of conifers up to one year of age. As will be noticed in the plates, the size of the seed influences directly the size of the seedling in its early life.

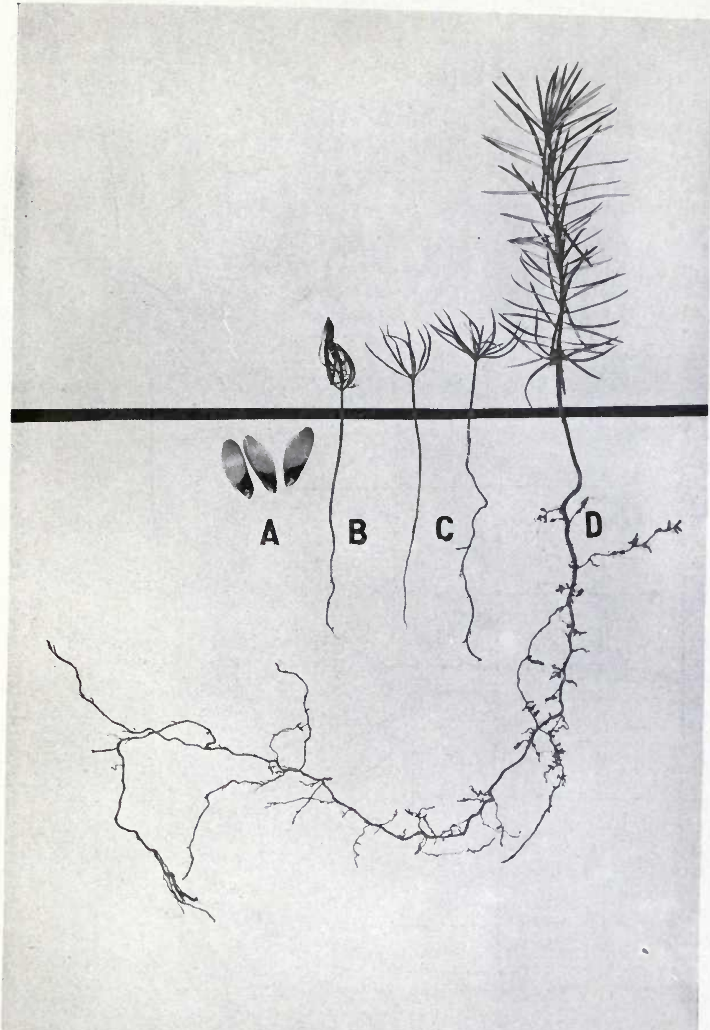

PLATE III
Pseudotsuga taxifolia
Douglas fir
(Size ⅔)

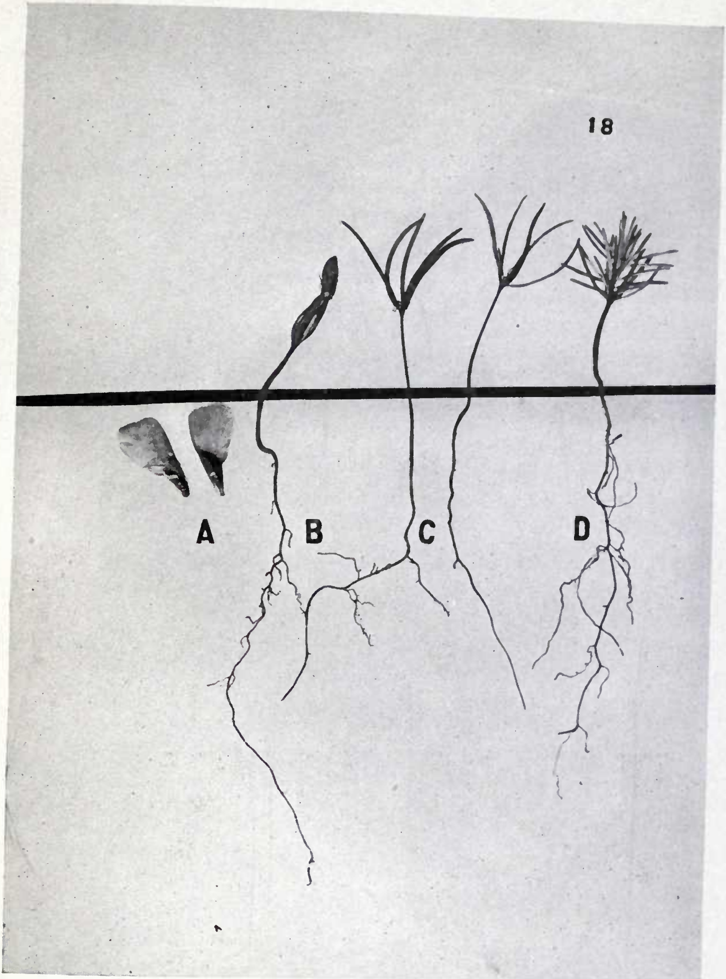

Plate IV
Abies nobilis
Noble fir
(Size ½)

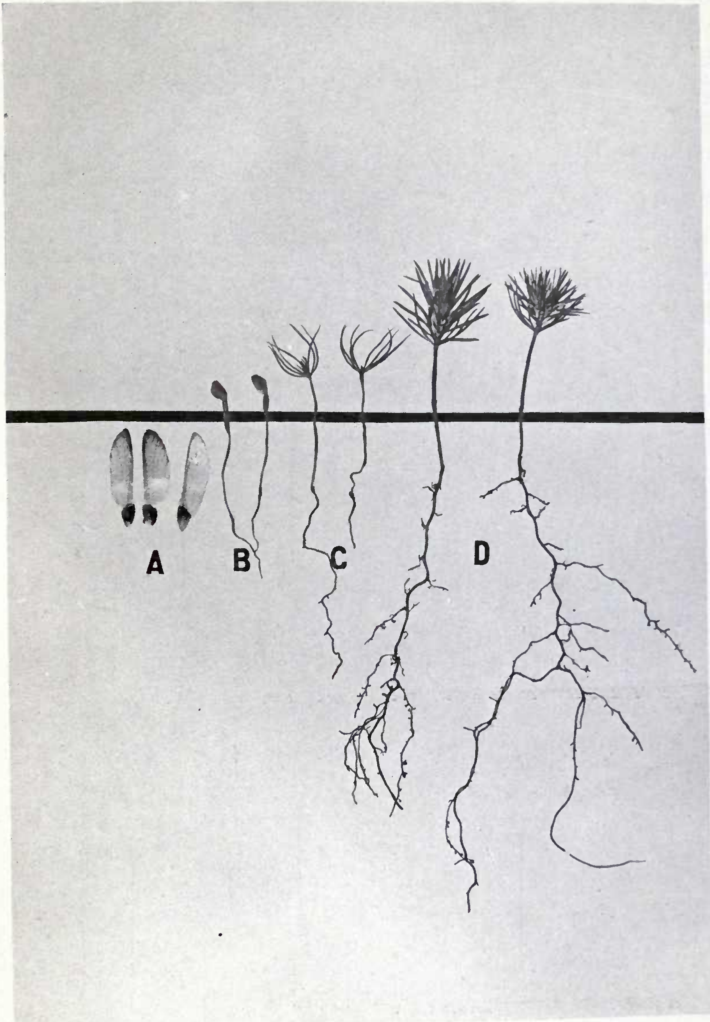

PLATE V

Pinus monticola
Western white pine
(Size ⅔)

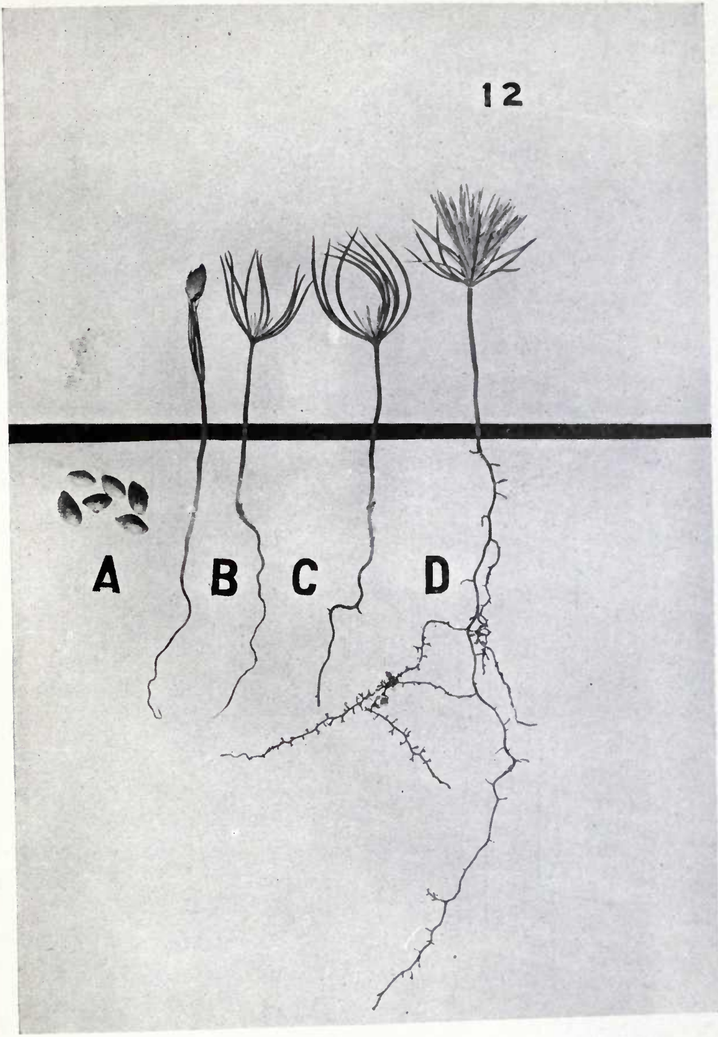

PLATE VI
Pinus strobus
Eastern white pine
(Size ⅚)

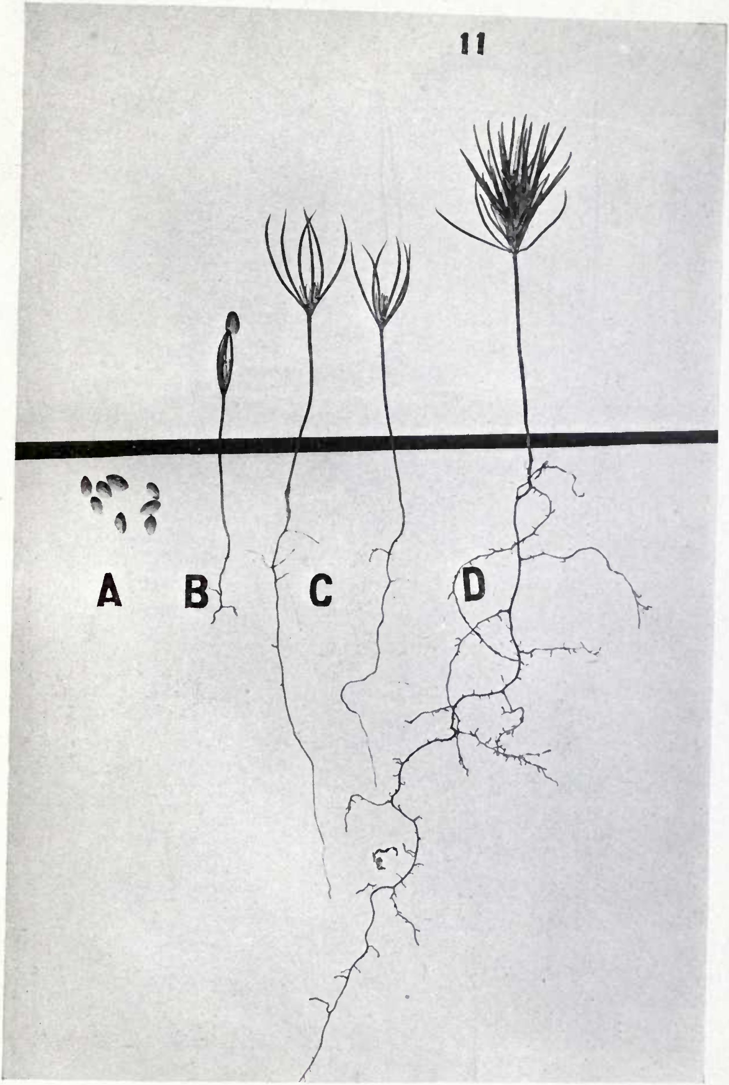

Plate VII
Pinus resinosa
Norway pine
(Size ¾)

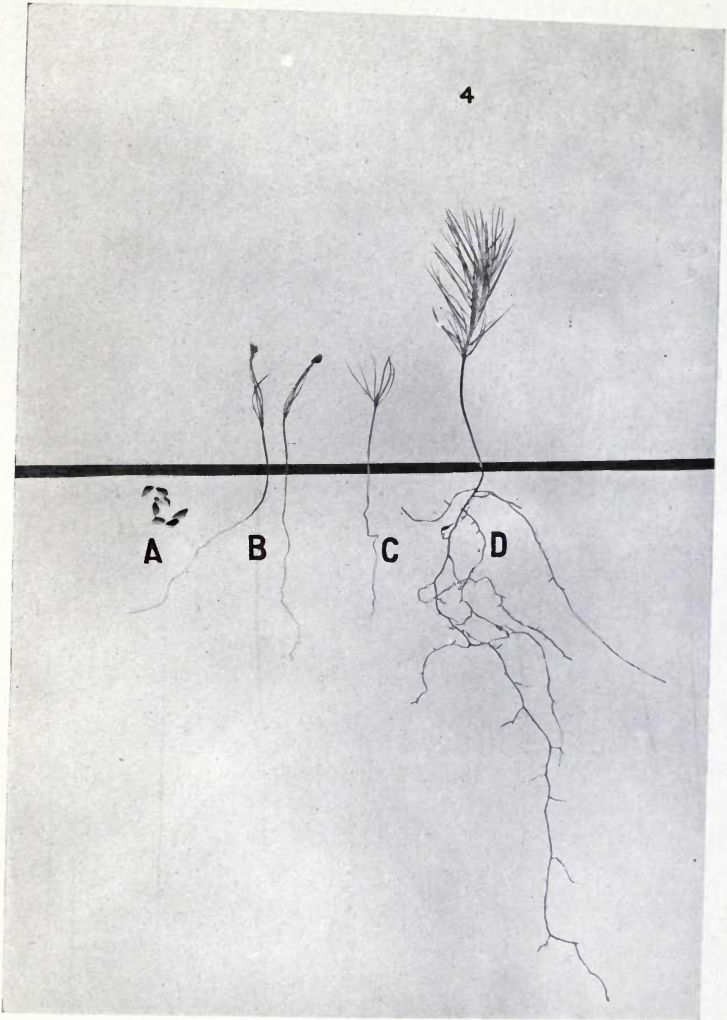

PLATE VIII
Pinus divaricata
Jack pine
(Size ⅝)

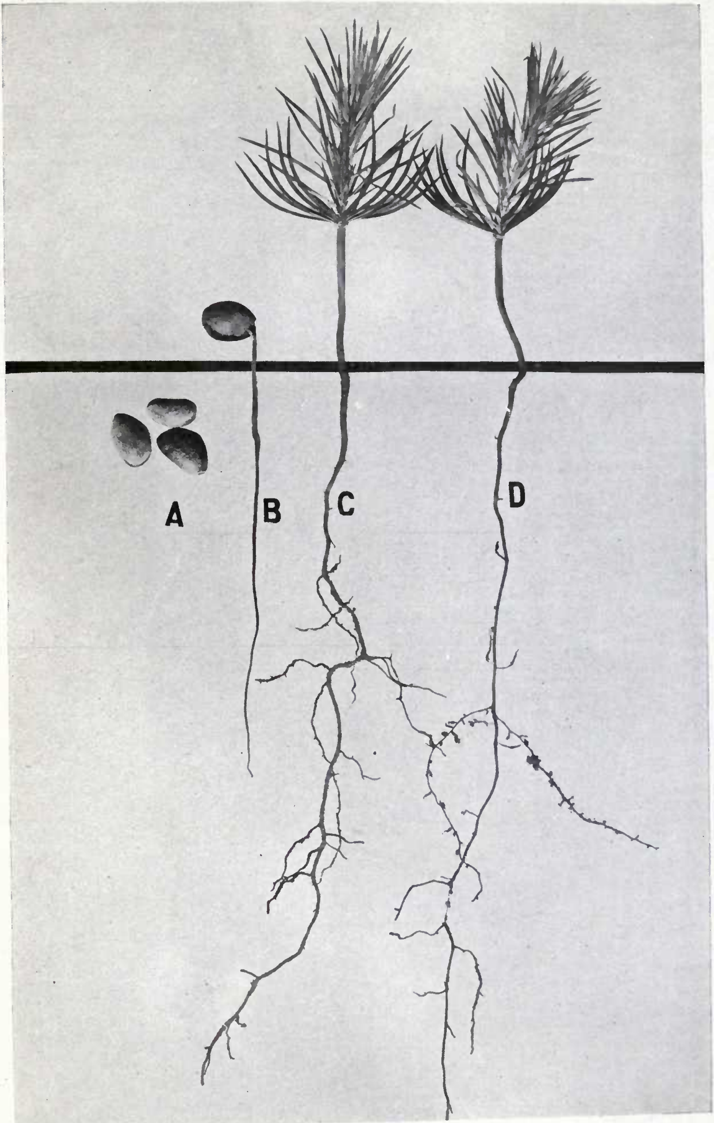

PLATE IX
Pinus lambertiana
Sugar pine
(Size ⅙)

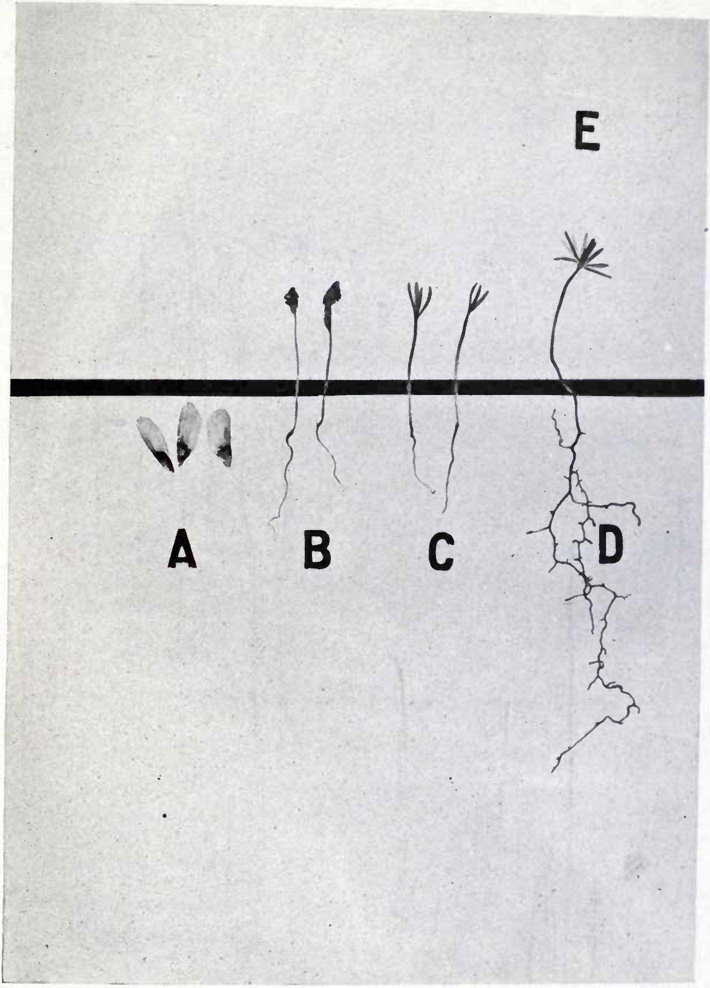

PLATE X
Tsuga mertensiana
Mountain hemlock
(Size ⅞)

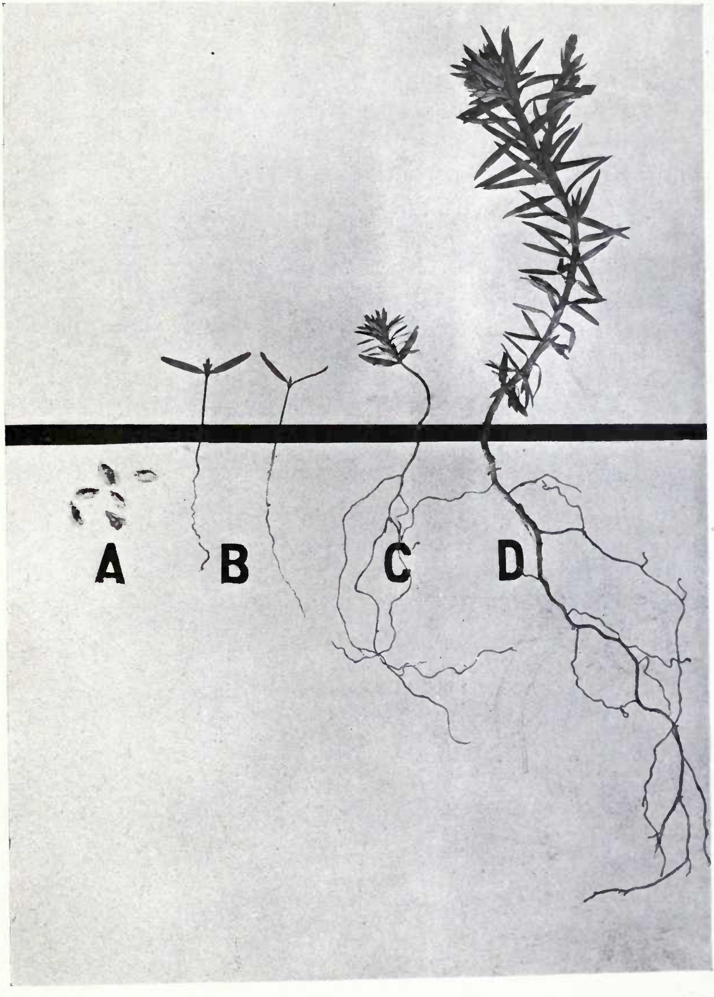

PLATE XI
Thuya plicata
Western red cedar
(Size ⅚)

DESCRIPTION OF PLATES

Plate III

A. Seed. Color: light reddish to a dark brown and lustrous above, pale white mottled with brown below, smooth.
Size: 4–6 mm. long; 2.5–4 mm. wide at the widest point, tapering to a point opposite wing. Wings dark brown, 6–8 mm. long, 3–4 mm. wide at widest part just below the middle, tapering to a rounding apex.
Weight: average 35,000 seeds per pound.

B. Seedling as it appears above ground, about to shed seed-coat. Hypocotyl green to reddish tinge, cotyledons green.

C. Seedlings with cotyledons; green. Cotyledons 1.5–2.5 cm. long; linear tapering point; 6–9 in number.

D. Seedling one year old. Showing remarkable root system adapting it to the drier slopes and causing unusually fast growth.

Plate IV

A. Seed. Color: pale reddish brown, slight tendency to be glossy. Wing very slightly lighter brown than the seed.
Size: 10–12 mm. long, 5–6 mm. wide at widest part near wing. Tapering to a point. Wing 10–15 mm. long, 12–15 mm. wide with widest part at top and forming a triangular shape with seed. Top also truncate.
Weight: 25,000 per pound.

B. Seedling as it appears above ground, about ready to shed seed-coat. Hypocotyl reddish green. Cotyledons green.

C. Seedlings in cotyledon stage. Cotyledons 2–3 cm. long, 4–7 in number, usually 6. Long slender, tapering point.

D. One-year-old seedling. A well developed plant.

Plate V

A. Seed. Color: pale reddish brown, mottled with black.
Size: 5–7 mm. long, 4–5 mm. wide at widest part; oblong to triangular in shape. Wings light brown, 1.5–2.5 cm. long, 5–7 mm. wide at widest point, just above the middle. Rapid taper from widest point to a rounded apex.
Weight: average 30,000 seeds per pound.

B. Seedling as it appears above ground; green—sometimes pinkish, about to shed seed-coat.

C. Seedling with cotyledons. Cotyledons 2–2.5 cm. long, 6–9 in number, tapering point.

D. Seedlings one year old, showing strong root system enabling the seedling to establish itself. True leaves in bundles of 5 do not appear until second season.

Plate VI

A. Seed. Color: reddish brown, sometimes lighter brown mottled with black. Wings dark brown.

Size: 5–6 mm. long, 3–4 mm. wide at widest part, oval to triangular shaped. Wings 1–1.5 cm. long, 5–6 mm. wide just above seed and tapering gradually to an almost pointed apex.

Weight: 35,000 per pound.

B. Seedling as it appears above ground, about to shed seed-coat.

C. Seedlings with cotyledons. Stem pinkish green. Cotyledons 1.2–2 cm. long, linear with tapering point.

D. Seedling one year old. True leaves in bundles of 5 do not appear until second year. Seedling well established at end of first season.

Plate VII

A. Seed. Color: dull chestnut brown, mottled with grey. Wings lighter brown with strips of darker brown.

Size: 4–5 mm. long, 2.5–3 mm. wide, almost round and oblong. Wings 1–1.5 cm. long and .5–.7 cm. wide at widest part near middle, tapering to oblique rounded point.

Weight: 60,000 per pound.

B. Seedling as it appears above ground, about to shed seed-coat. Pinkish stem.

C. Seedling with cotyledons. Stem pinkish color. Cotyledons green, linear 2–2.5 cm. long tapering point. 5 to 7 in number, usually 6.

D. Seedling one year old, showing that it is well established at this age.

Plate VIII

A. Seed. Color: almost black, dull brown spots. Wings very light brown with darker brown stripes and margin.

Size: 4 mm. long, 2 mm. wide at widest part, triangular in shape. Wings 8 mm. to 1 cm. long, 3–4 mm. wide at widest part near middle, broad rounded apex.

Weight: 120,000 per pound.

B. Seedlings as they appear above ground, about to shed seed-coat. Hypocotyl pale pink.

C. Seedlings with cotyledons. Cotyledons 1.2–1.8 cm. long, narrow long tapering point, green. 4–7 in number.

D. Seedling one year old. Well established as shown by root system.

Plate IX

A. Seed. Color: dark brown, shiny on one side—side next to cone—and a greyish brown on other side. Wings dark brown.
Size: 1–1.5 cm. long, 1–1.2 cm. wide. Very thick, oblong to triangular shape. Wings 1.5–1.8 cm. long, 1.5 cm. wide. Widest at top with very slightly rounded top.
Weight: 2,370 per pound.

B. Germinated seed just as seed-coat pushes above ground, showing deep root developed.

C. and D. Seedlings one year old. Well developed root systems. Cotyledons 3.5–4 cm. long. Green, 12–16 in number, tapering point. Stem reddish green. True leaves in bundles of 5 do not appear until second season.

Plate X

A. Seed. Color: brown to deep reddish brown. Wings pale brown merging to a reddish brown where wing is attached to seed.
Size: 2 mm. wide, 5 mm. long, triangular shaped. Wing 5–6 mm. wide at widest part near top. 1 cm. long. About equal width throughout with broad rounded apex.
Weight: 260,000 per pound.

B. Seedlings as they appear above ground. Hypocotyl reddish tinge. Cotyledons pale green.

C. Seedlings with cotyledons. Cotyledons 4–5 mm. long, linear with short tapering points. Midrib not as distinctive as in *Tsuga heterophylla.* 3–5 in number, usually 3 or 4.

D. Seedling one year old.

Plate XI

A. Seed. Dry. Color: brown with lighter brown wings.
Size: 3 mm. long, narrow; wings 4 mm. long and 3 mm. wide including wings. Wings usually unequal, forming obcordate apex with seed.
Weight: 220,000 per pound.

B. Seedling with cotyledons. Hypocotyl pale pink color; cotyledons linear 6 mm. long, green, two in number.

C. Seedling one year old.

D. Seedling three years old. First true leaves forming. This shows that it takes the seedling a long time to establish itself and that it must have favorable conditions for more than one season.

A study of the foregoing plates will show the nature of the early development of these species. The noticeable thing is that the species which require the greatest amount of moisture are the ones in which the seedlings are slow in establishing themselves. The natural result of this is that these species are always found near the streams and on moist slopes. Cedar requires about three years to establish its seedlings, while a sugar pine or Douglas fir seedling is well established at the end of the first season. Hemlock is another example of a species with a small seedling during the first year, although it will produce a greater height growth than its associates after the seedling is established, that is, after the third or fourth year. It is clearly seen also that species which have large seeds establish their seedlings early, enabling them to live in places unfavorable to smaller-seeded species.

Viability of Seed

seeds treated with chemicals

The following experiments for viability tests of the seed of *Pinus monticola* showed that the seed will stand rigorous treatment and still germinate. No attempt was made to duplicate conditions as they might exist in the litter and duff on the forest floor, but rather to test out the limit of endurance of the seed.

Copper acetate. Five treatments were given varying in strength from four ounces to thirty-two ounces of copper acetate per gallon of water in which the seed was soaked for two hours. Germination was not affected and gave the same results as the untreated plot.

Six treatments with strengths varying from two to four ounces per gallon of water in which the seed was soaked from twelve to twenty-four hours showed no effect on the germination. Traces of blue coloring in the endosperm of all of the treated seed showed that the solution had penetrated the seed-coats. This coloring was quite noticeable in the use of the stronger treatments. Some of the more strongly treated plots gave as good germination as those untreated, showing that the vitality of the seed was unimpaired. The seedlings that came up were thrifty and the root systems were well developed.

Zinc chloride. Eight treatments were used varying in strength from two ounces of zinc chloride to one gallon of water, up to sixty ounces of zinc chloride to one gallon of water. Seed soaked for two hours showed no effect on germination.

Four treatments, from 3/8 to one ounce of zinc chloride to one gallon of water applied to seed for thirty minutes, did not affect germination.

Ten treatments, varying from one part of zinc chloride to fifty parts of water by weight, up to one part zinc chloride to five hundred parts water; and ten treatments, varying from one part zinc chloride to three

parts of water by weight, to one part of zinc chloride to forty parts of water, all showed no influence on the germination. Zinc chloride has been found to be a stimulant to germination in the work done in soil treatment for fungi, and was expected to be a stimulant in germinating the white pine seed, but such did not prove to be the case.

Ether. Seven treatments of ether, varying from dipping to exposing the seed to the ether fumes for four hours, showed that the seeds were killed if left in the fumes for more than one hour. Liquid ether was put into a bottle and the seed suspended above it on a gauze, thus subjecting the seed to the ether fumes. The bottle was closed with an air-tight glass stopper.

Seed soaked in water. Seed was put into water at the following temperature in degrees Fahrenheit and left for forty hours: 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 212. The temperature of the water was 65° to 70° F. when the seed was taken out. No germination was obtained above 150° F., but the seed soaked in 140° germinated 10 per cent as compared with 4 per cent in the unsoaked seed, showing that this temperature had stimulated germination.

Sulphuric acid. The following table shows the results of treatments of western white pine seed with sulphuric acid.

TABLE V

Treatment of Seed	Number Days before First Germination	Germination Per Cent 15 Days after First Germination in Series	Germination Per Cent 50 Days after Planting	Condition of Seed when Planted
Dipped A	23	2.8	4.0	Exocarp charred by acid
F-A-5	19	3.2	5.0	Exocarp charred by acid
F-A-10	26	1.6	3.2	Exocarp and mesocarp charred
F-A-15	19	1.6	3.2	Exocarp and mesocarp charred
F-A-30	23	1.2	3.0	Exocarp and mesocarp charred
F-A-45	19	2.4	7.4	Exocarp nearly removed and mesocarp and endocarp charred
Untreated	26	1.0	2.0	Normal
Untreated	21	1.2	2.0	Normal
½-A-30	21	1.6	3.2	Not discolored, seedcoats intact
½-A-60	21	1.6	3.4	Not discolored, seedcoats intact
½-A-120	37	0.0	2.0	Not discolored, seedcoats intact
½-A-180	21	0.8	2.2	Not discolored, seedcoats intact

A =Commercial sulphuric acid.
F-A-5=Seed soaked in acid, full strength, for 5 minutes, etc.
½-A =One-half strength acid, that is, equal parts with water.

PLATE XII

View on Oregon National Forest in northern Oregon showing the results of a second fire. This area was burned over in 1902 and followed by dense reproduction of Douglas fir, noble fir, hemlock, and cedar. The second fire ran through in 1909. Note that the second fire is not followed by reproduction.

Plate XII

Commercial sulphuric acid chars the seed-coats as soon as the seed is immersed. Where the seeds were left for thirty minutes and more in the full strength acid, the seed-coats could all be removed by slightly rubbing the seed, thus leaving the endosperm naked. Even in this condition, the viability of the seed was unimpaired, and, as the table shows, the strongest treatment gave the best germination results.

Seed treated with half strength acid showed no appreciable effects upon the seeds or on the germination.

Germination in all of the plots was perfectly normal. Seedlings in all the treatments appeared healthy and thrifty. Seedlings in the plots treated with the full strength acid for the longer periods appeared above ground, bringing up the endosperm without the seed-coat, and in some cases the cotyledons grew out through the sides of the endosperm. Seedlings appearing in this way produced strong, vigorous plants however.

Seed that was soaked in C. P. sulphuric acid for one hour was covered with water after the acid was poured off. The reaction created a temperature of 168° F. The exocarp was charred and most of it destroyed by the acid. The mesocarp and endocarp were also charred so that they rubbed off easily, but the endosperm or food material of the seed was apparently uninjured. Some of the seed germinated. Seed soaked for more than one hour and treated with water failed to germinate.

Aside from the experiments made to test out what severe conditions seeds will withstand and still retain their viability, the following chemical experiments to determine influence on germination were done with the same species, *Pinus monticola.*

Copper sulphate. Ten treatments, varying from one part copper sulphate to one part of water by weight, up to one part copper sulphate to five and one-half parts of water, showed that germination was stimulated by the chemical. The seed-coats opened in a few days, but as soon as they separated the copper sulphate solution stained and killed the germinating seed.

Copper acetate. Ten treatments, varying from one part copper acetate to one part water by weight, to one part copper acetate to five and one-half parts of water, showed that germination was stimulated by the copper acetate, but the growing tips were killed as soon as they appeared. Chemical injury occurred in all of the strengths used. In the weaker treatments, the germinating tips were stained blue, and in the stronger treatments the entire endosperm and plumule were stained blue.

The above experiments show that the seed in the dormant state will withstand very severe conditions, but is quite easily killed after germination begins. The chemical condition of the forest floor may therefore influence the viability of the seed and also be a major factor in determining the length of the period through which the seed will lie dormant and retain its viability.

It is known that seeds of other plants are viable for long periods, and the writer has known wild oat seed (*Avena fatua*) to remain in soil for seven years and produce a good germination the year it was plowed up.

Becker[2] draws the conclusion that oxygen acts as a stimulant in seed germination, and many of the conditions under which the seed germinates or does not germinate seem to bear this out.

Hatfield's[3] work on the *Vitality of Seed* showed that the *Hibiscus militaris* germinated after ten years, Rocky Mountain columbine after six years, tobacco, verbenas, ageratum, after several years' storage.

Duval[4] found the following seeds germinated after being buried in layers of clay, not below the frost line, for three and a half years: *Trifolium pratense*, *Trifolium repens*, *Polygonum avariculare*, *Bursa pastoris*, *Anthemis cotula*. The soil was taken into the greenhouse and the seed germinated.

Beal[5] secured some germination from the following seeds after they had been stored in soil for twenty years: *Amaranthus retroflexus*, *Brassica nigra*, *Capsella*, *Bursa pastoris*, *Lepidium virginicum*, *Anthemis cotula*, *Malva rotundafolia*, *Rumex crispus*, *Verbascum thapsus*, *Stellaria media*, *Polygonum hydropiper*.

These experiments give some idea as to the viability of the seed of some of the common and well-known weeds. Most of these have seeds with very thin seed-coats that are easily soaked with water. It is very probable that seed of the conifers with more or less resinous seed-coats would remain viable for a longer period. The characteristics of some of the coniferous seeds are well known, such as the western white pine, Douglas fir, eastern white pine, and the junipers. The seeds of these will often not germinate for two or three years even under the best of conditions in the nursery. Certainly they will remain viable as long or even longer when in the forest floor under unfavorable germinating conditions, but at the same time under good storage conditions.

Conzet[6] showed that the seed of the Norway pine (*Pinus resinosa*) remained in the forest floor for three years and then produced good germination.

The results of the study of the Yacolt burn are a practical demonstration of the viability of coniferous tree seeds. The study showed that reproduction occurs over the entire burn. The seedlings which germinated from one to three years after the fire vary in density, regardless of the location of seed trees, while the seedlings germinating later than this

[2] H. Becker, Über die Keinung verschieden artiger Fruchte und Samen bei derselber Species. *Beihefte Botanisches Centralblatt* 29:21-143. 1912.

[3] T. D. Hatfield, Vitality of seed. *Garden and Forest* p. 297. 1897.

[4] Duval, in the *Botanical Gazette* 37:146-47. 1904.

[5] Beal, Vitality of seeds. *Botanical Gazette* 37:222. 1904.

[6] G. M. Conzet, A qualitative and quantitative study of the seed production and reproduction of Norway pine (*Pinus resinosa*). Master's thesis, the University of Minnesota. 1913.

are almost all in close proximity to seed trees. At a distance of one or two miles from seed trees, the reproduction was in many instances much more dense than it was near the trees, often reaching 20,000 to 30,000 seedlings per acre. The distance from the seed trees and the erratic occurrence of the dense stands of seedlings, sometimes near seed trees and sometimes at great distances from them, showed that the seed had not been blown in by the wind since the fire. The areas of dense stands of reproduction ending in very irregular edges, beyond which no reproduction occurred, were convincing evidence that the seed producing the stands was present before the fire. These irregular edges showed where the ground fire which consumed all the duff had died out. Where the duff was left unburned the reproduction occurred. In all cases where reproduction occurred in burns, the burned trees of the species comprising the reproduction were found in the immediate vicinity.

When the Yacolt fire occurred in the early part of September, 1902, all of the timber was killed and the seed of that year's crop was badly scorched or burned. This is shown by the fact that there were no unburned cones or cone scales present on the burned-over areas, while charred cones and cone scales, as well as seeds of all of the species burned, were found. Also in the places where the surface of the litter and duff was charred, but undisturbed since the fire, seeds were found buried in the duff, some of which still had perfect wings. These facts are further strengthened by the appearance of the clear-cut margins and abrupt endings of the areas of good reproduction where 30,000 or more seedlings per acre occur, showing that the seed was in the litter and duff, and lived through the fire. That a large per cent of this seed germinated during the first season is shown by the large percentage of eleven-year-old seedlings. The five to ten year age class showed the distribution of the seedlings that came from the seed which germinated some years after the fire. Those of the older age classes at great distances from the seed trees, undoubtedly came from the seed which had remained dormant in the litter or duff and escaped the fire, as usually no seedlings under five years of age were found in these localities. In the case of the western white pine, there were no seedlings under five years old found during the entire study, although older white pine seedlings were distributed over the entire area. This indicated that the white pine seeds remained viable for six years under the conditions to which they were exposed. White pine seeds were found in some of the charred cones and also some in the litter and duff, but these undoubtedly were killed by the fire or were not viable.

The fire advanced before a southeast wind and the effects of it are recorded in the sparse reproduction on the south and southeast slopes where the fire was hottest and where all of the litter and duff was burned. On these slopes there were no areas of reproduction, only occasional

scattered seedlings, showing that very little seed was left after the fire, while on the slopes not struck by the direct flames of the fire, reproduction occurs in very dense stands regardless of the distance from seed trees.

Reproduction was found at distances of one or two miles from the nearest seed trees. In the case of the white pine, there are no seed trees on the township that could have any influence whatever on the area over which the reproduction of this species extends. Without a doubt the seed was there before the fire passed over the area, and escaped destruction. This seed may have dropped from the trees the year previous to the fire or even earlier, as must be the case where heavy stands of reproduction appear during the first season following the fire, since a dense stand of reproduction is not due to a single crop of seed but rather to an accumulative crop of several years. If the seed produced the same year the fire passed over the area was not killed, this study shows that this seed must lie dormant in the forest floor for several years. The indications are that the white pine remained six years; Douglas fir, six years; noble fir, three years; amabilis fir, five years; hemlock, three years; and yew was found scattered over the typical slopes of this species, varying in years from eleven to three, showing that the seed remained dormant for eight years. The yew was a good index in accounting for the seed on the area, as there is no question about the wind distribution of the berry-like seed. The theory that animals carried the seed can not be accepted because the seedlings invariably appear among the burned snags of yew, whereas animal distribution would not be confined to these areas.

These conditions are duplicated on all of the burns gone over on the Snoqualmie National Forest in northern Washington and the Oregon National Forest in northern Oregon. The burns on these forests were not studied, but general observations indicated that the conditions were the same as those found on the Columbia. The noticeable feature here was the absolute lack of reproduction after a second fire except very near to seed trees. This fact shows that good and wide-spread reproduction following a first burn comes from seed stored in the forest floor, and can not be attributed to seed furnished by a few surviving trees. Single seed trees surviving a second fire never restock an area except in their immediate vicinity. If a few escaped trees could restock a burn they would also restock a second burn on the same area.

Summary and Conclusions

All forest tree species in forest stands produce sufficient seed to reëstablish their own type under favorable conditions, and a change of type or removal of a forest from any area once covered with a forest is due to other factors than production of seed.

Species producing large seeds produce comparatively few in number.

Seed distribution is one of the important factors controlling the establishment of a forest type.

In the white pine region of Idaho, reproduction by wind-blown seed can not be depended upon for more than 150 feet from the seed trees.

In the Douglas fir region of the Cascades along the Columbia River, reproduction by wind-blown seed of Douglas fir and its associates can not be depended upon for more than about 300 feet from the seed trees.

Germination conditions are often unfavorable in a shaded and cool forest floor, hence seed may lie dormant for long periods.

By the removal of a forest, germinating conditions are improved, and the dormant seed germinates.

Moisture is the chief factor in the establishment of the seedling, while temperature is often a more important factor in germination.

The size of the seedling during its early life is directly proportional to the size of the seed.

A seedling from a large seed becomes permanently established much earlier than a seedling grown from a small seed, hence the former is able to obtain and hold possession of the more unfavorable sites.

Seed is always present in the forest floor, generally covered with and mixed in a layer of litter and duff.

This seed is a source of reproduction following forest fires or logging operations.

Some seed while dormant will withstand severe conditions, as shown by chemical tests.

Coniferous seeds are known to be viable after two to eight years of storage in the forest floor.

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